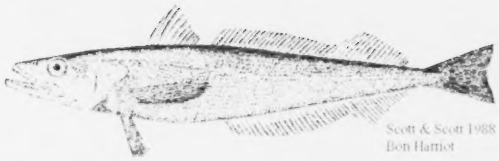
2012 ASSESSMENT OF 4VWX SILVER HAKE



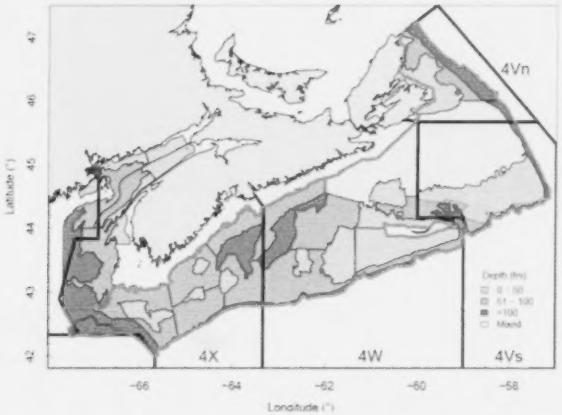


Figure 1. Northwest Atlantic Fisheries Organization (NAFO) Divisions 4VWX and associated DFO summer Research Vessel (RV) survey strata outlined in blue. Red outline represents the survey strata used to assess 4VWX silver hake.

Context

Silver hake (Merluccius bilinearis) is a bottom dwelling member of the cod family, occurring in the northwest Atlantic from Cape Hatteras to the Gulf of St. Lawrence. A major concentration of silver hake occurs on the Scotian Shelf.

A silver hake fishery has been conducted on the Scotian Shelf (NAFO Divisions 4VWX) since the early 1960s, primarily by the distant water fleets of Russia, Cuba, and Japan in the early years. Prior to 1977, fishing on the Scotian Shelf was unrestricted in terms of area, mesh size and season. From 1977 to the early 2000s, the foreign fleet was restricted mainly to the shelf edge. Since 1995, a fishery has been conducted by the Canadian tonnage class 3 (<65') mobile gear fleet in and around Emerald and LaHave basins.

The last assessment of 4VWX silver hake was conducted in November 2009 (DFO 2010). An updated assessment was requested by Resource Management to provide scientific advice in support of the fishery in the Maritimes Region, specifically to review and evaluate the current status of 4VWX silver hake based on the latest information from fisheries and research surveys, to evaluate the potential consequences of different harvest levels during the 2013/2014 fishery on stock abundance and exploitation rate, to identify appropriate reference points, and to evaluate the current status in relation to these reference points.

This Science Advisory report is from the December 11, 2012, Review of the Framework and Assessment for 4VWX Silver Hake: Part 3 – Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Landings of 4VWX silver hake in the fishing years ending in 2010 and 2011 were 8,396 and 9,231 mt, respectively, relative to a quota of 15,000 mt. Landings are constrained by market conditions; there is no indication that a catch lower than the quota is related to reduced abundance.
- The current silver hake fishery catches primarily fish aged 1-2.
- Total survey biomass has increased to levels comparable to the late 1980s. Age 2+ (a proxy for spawning stock biomass) and 2+ female biomass have also increased.
- The 2009 year class is the largest in the time series. The incoming 2010 and 2011 year classes are both above average.
- Condition has been generally below the long term average since the early 1990s and is currently near the lowest level in the time series.
- The 2011 (123,000 mt) and 2012 (120,000 mt) model estimates of population biomass were the highest for the 1993-2012 time series.
- The current median estimates of stochastic Maximum Sustainable Yield (MSY), Biomass at MSY (B_{MSY}), and Fishing Mortality at MSY (F_{MSY}) for 4VWX silver hake are 16,000 mt, 59,000 mt, and 0.32, respectively.
- 80% B_{MSY} is proposed as the Upper Stock Reference (USR=47,200 mt) and 40% B_{MSY} is proposed as the Lower Reference Point (LRP=23,600 mt) for 4VWX silver hake. F_{MSY} is proposed as the limit Removal Reference (RR=0.32).
- Biomass is expected to be lower in June 2013 and March 2014 than in 2012 regardless of the landings in the 2012/2013 fishing year.
- Across all landings scenarios examined in the projections (Total Allowable Catch = 0-18,000 mt), the probability of biomass falling below 80% B_{MSY} in July 2013 was less than 0.1. With landings at F_{MSY} (45,100 mt), the probability of falling below 80% B_{MSY} increases to 0.13. The probability of projected March 2014 biomass falling below these reference levels was less than 0.15. With landings at F_{MSY}, the probability of falling below 80%B_{MSY} increased to 0.32.
- Projections from an aggregate population model, such as that used here, assume mean recruitment and growth across the projected years. The ability of the model to describe future biomass more than one year ahead is uncertain given that silver hake have highly variable recruitment patterns and the fishery prosecutes recruiting individuals (ages 1-2).
- The restrictions on geographic extent of the fishery may preclude exploitation as high as F_{MSY}, since this may represent a higher proportion of the stock biomass than is present in Emerald and LaHave basins and available to be caught.
- Based on observer records, bycatch constitutes less than 4% of the total observed catch.
- The fishery occurs primarily on soft-bottom habitat in Emerald and LaHave basins. A part of a globally unique population of the large-structure forming sponge, *Vazella pourtalesi*, is also found in this area and is known to be vulnerable to bottom-tending fishing gear.

INTRODUCTION

Rationale for Assessment

An assessment was requested by Fisheries and Oceans Canada (DFO) Resource Management to provide science advice in support of the fishery in the Maritimes region. The specific objectives were:

- Review and evaluate the biological and fishery information on 4VWX silver hake status and characterize the uncertainty of the results, highlighting any trends in distribution, biomass estimates, length and age composition, and condition over the long term (length of the assessment);
- Evaluate the potential consequences of different harvest levels during the 2013/2014 fishery on stock abundance and exploitation rate;
- Identify appropriate reference points and evaluate the current status in relation to these reference points.

Biology

Silver hake (Merluccius bilinearis) is a bottom dwelling member of the cod family found in the Northwest Atlantic from Cape Hatteras to the Grand Banks and the Gulf of St. Lawrence. Based on analysis of summer research vessel (RV) survey data, the most stable habitat association for small silver hake (<20cm) was that with depth; fish are captured in the summer at a much higher rate at depths between 150 and 200 m across all years. The distribution of juveniles and adults is associated with warm bottom temperatures of 5-10°C. Based on analysis of summer RV survey data, silver hake, regardless of size, were found in higher water temperatures than many other species with an overall mean temperature of 8.3°C. Silver hake are sexually dimorphic, with females growing faster and living longer than males. Maximum age is 12 years. Maturity is reached relatively early, with a majority mature by age 2.

A major concentration of 4VWX silver hake (Figure 1) occurs on the Scotian Shelf and is considered a self-reproducing stock. This population aggregates along the shelf edge and in the deepwater depressions of the Scotian Shelf in Emerald and LaHave basins. Seasonal movements occur during the spawning period from July to September when large numbers occur on the shelf in the shallow waters around Emerald, Western and Sable Island Banks. On the Scotian Shelf, silver hake feed mainly on shrimp, sand lance and krill. From analysis of the Maritimes Region stomach database, the main finfish predators of silver hake are monkfish, pollock, Atlantic halibut and cod. Analysis of seal diets on Sable Island indicates that silver hake are also a prey item for seals.

ASSESSMENT

The Fishery

Landings averaged over 90,000 mt in the 1970s, 60,000 mt in the 1980s and 30,000 mt in the 1990s but have been at lower levels since 2000 (Table 1, Figure 2). The TAC has been set at 15,000 mt since 2003, but landings have been lower, averaging 11,100 mt for the years 2003-2011. Landings are constrained by market conditions; there is no indication that reduced catch, or a catch lower than the quota, is related to reduced abundance. Landings of 4VWX silver hake in the fishing years ending in 2010 and 2011 were 8,396 mt and 9,231 mt, respectively. For the current fishing year, landings in the fishery from April 1 through December 12, 2012 were 5,759 mt.

For many years the silver hake fishery was concentrated on the shelf edge and was conducted by foreign fleets. Since 2004, all catches have been taken by Canadian vessels, mainly in Emerald and LaHave basins (Figure 3).

Table 1. Landings and TAC of silver hake in 4VWX (thousands mt).

Year	1970-79	1980-89	1990-99[2]	2000[3]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
TAC	90.2[4]	98.5	53.3	20	20	20	15	15	15	15	15	15	15	15	15
Canada[1]	0	0	3.7	12.9	18.0	15.7	12.2	12.8	11.8	12.3	12.0	12.1	10.4	8.4	9.2
Foreign	115.6	64.2	27.8	0	0	0	0	0	0	0	0	0	0	0	0
Total	115.6	64.2	31.5	12.9	18.0	15.7	12.2	12.8	11.8	12.3	12.0	12.1	10.4	8.4	9.2

1. Includes developmental allocations fished by foreign flagged vessels, ending in 2004.
2. Fishing year, landings and TAC refer to the 15 month period from January 1, 1999 to March 31, 2000.
3. Commencing in 2000, fishing year, landings and TAC refer to the period from April 1st of the current year to March 31st of the following year.
4. Averaged TAC for 1974-79 period.

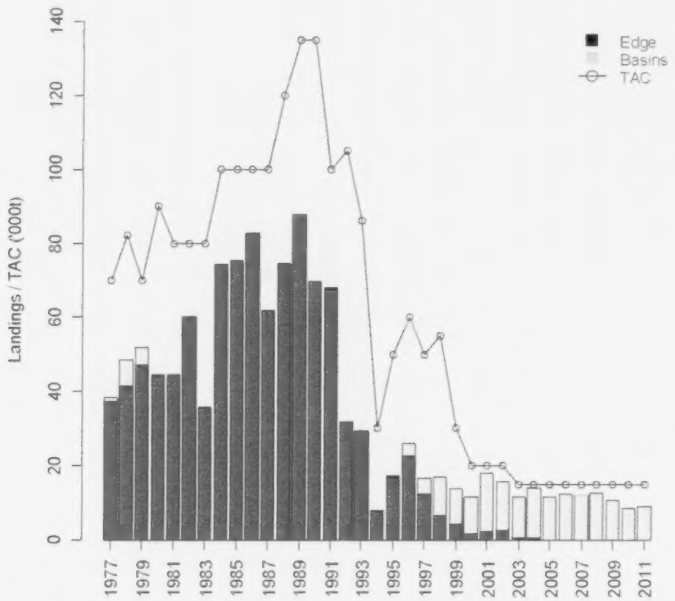


Figure 2. Time series of landings and TAC for 4VWX silver hake separated into shelf edge and basin areas.

The age composition of the silver hake fishery shifted from predominantly ages 2, 3 and 4 in the 1970s and 1980s to ages 1 and 2 by the mid-1990s (Figure 4). This temporal shift occurred during the transition from the foreign fishery on the shelf edge to the domestic fishery in the basins. The domestic fishery also used codends with 55 mm square mesh rather than 60 mm diamond mesh and separator grates, resulting in changes in gear selectivity. The current silver hake fishery catches fish primarily aged 1-2. The strong 2009 year class made a significant contribution to the catch at age 2 in 2011.

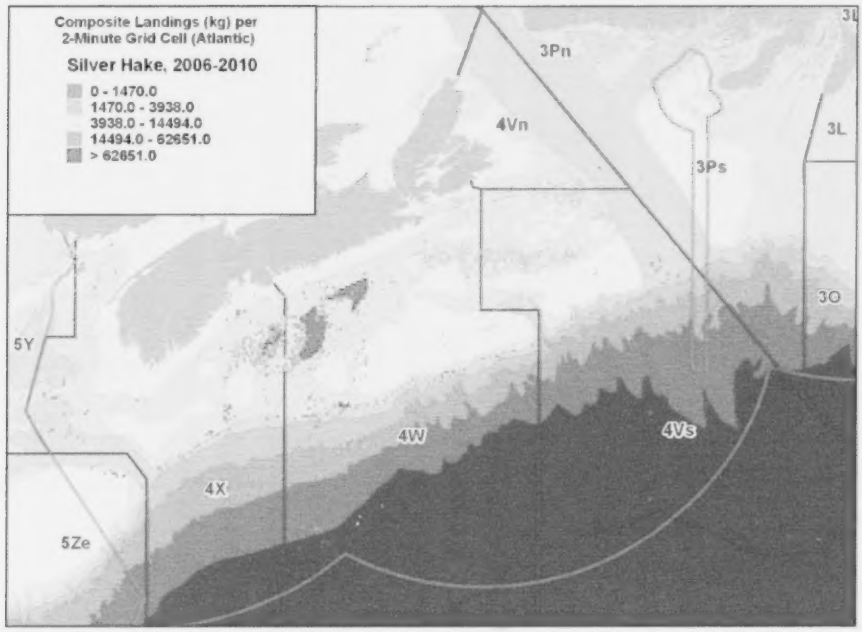


Figure 3. Location of 4VWX silver hake landings from 2006-2010, including fishery landings and bycatch. Note that the majority of the directed silver hake fishery occurs within Emerald and LaHave basins. Colour scale represents fishing intensity as total weight of fish (kg) landed per two minute cell from lowest (green) to highest (red).

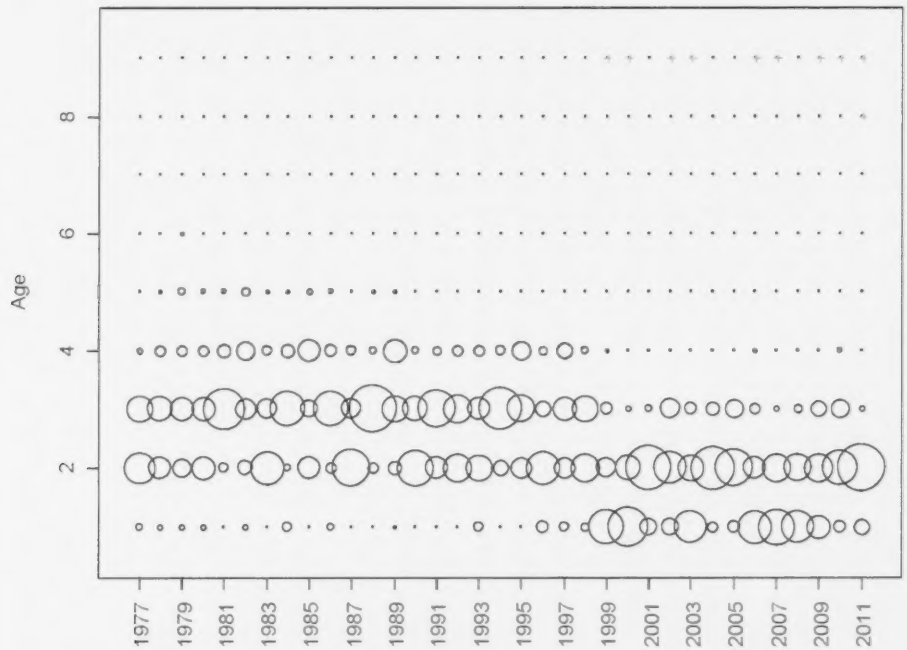


Figure 4. 4VWX silver hake fishery catch at age for 1977 - 2011, ages 1-9. Bubble diameter is relative to the proportional contribution by each age to the annual catch. Red crosses represent no catch of that age class.

Research Surveys

All DFO summer RV survey trends are based on analysis of strata 440-483 (shown in red in Figure 1).

DFO summer RV survey trends in biomass show relatively high levels in the early to mid-1980s, followed by a decline to relatively low levels from the late 1980s to the early 1990s (Figure 5). Biomass was variable from the mid-1990s to mid-2000s, with peaks in 1996, 2001 and 2004. Since 2008, total survey biomass has increased to levels comparable to the late 1980s. Both the age 2+ biomass (a proxy for spawning stock biomass) and 2+ female biomass have also increased since 2008.

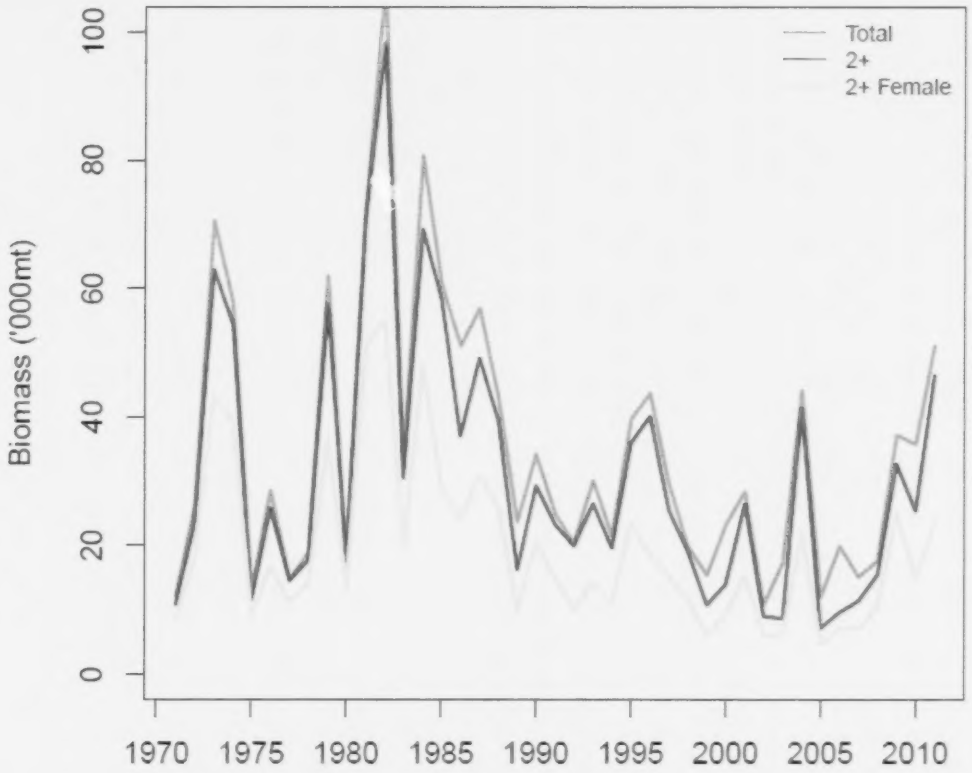


Figure 5. Stratified total biomass indices from the DFO summer RV survey for strata 440-483, 1971-2011. Total: ages 1-9, sexes combined; 2+: ages 2+, sexes combined; Female 2+:ages 2+ females only. Prior to 1982, biomass was multiplied by 2.3 to correct for vessel effects.

Survey catches have been dominated by ages 1-3 throughout the time series. The 2009 year class appears strong at age 1 in 2010 and at age 2 in 2011 (Figure 6).

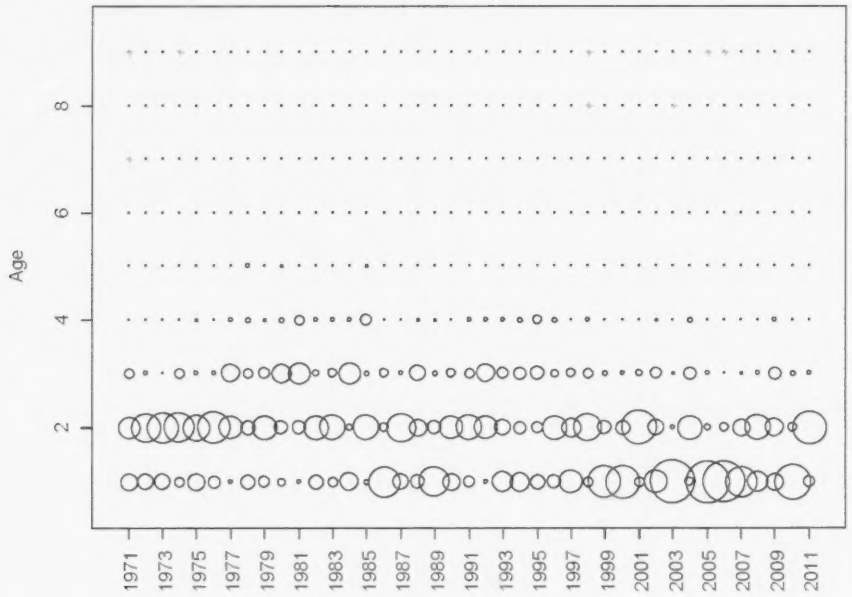


Figure 6. Stratified total number per tow at age (1-9) for silver hake from the summer RV survey, strata 440-483, 1971-2011. Bubble diameter is relative to the proportional contribution by each age to the annual catch. Red crosses represent no catch of that age class.

Recruitment has been variable but generally above the long-term average in recent years (Figure 7). The 2009 year class is the largest in the time series. Current prospects for the 2011 year class (based on survey length data) are that it is above average.

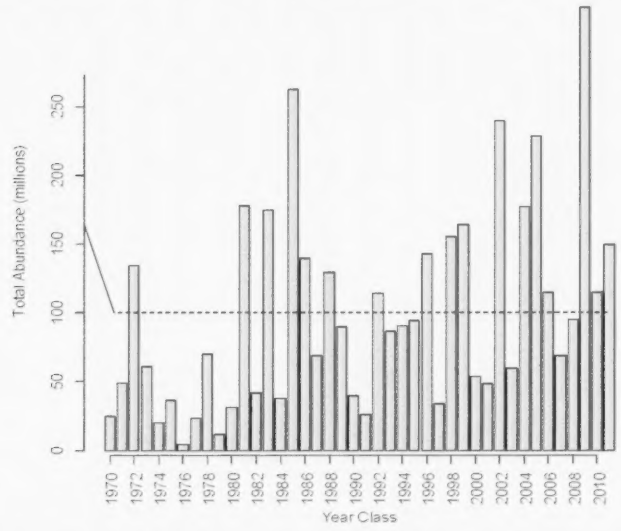


Figure 7. Recruitment estimates for Scotian Shelf silver hake from age 1 summer RV survey abundance. Long term average(1970-2011) indicated by dashed line. The 2011 year class is estimated from 2012 summer RV survey length data.

Physiological condition, estimated by Fulton's K (K=weight/length^3) for 21-44 cm fish, has generally been below the long term average (1970-2012) since the early 1990s and is currently near the lowest level in the time series (Figure 8).

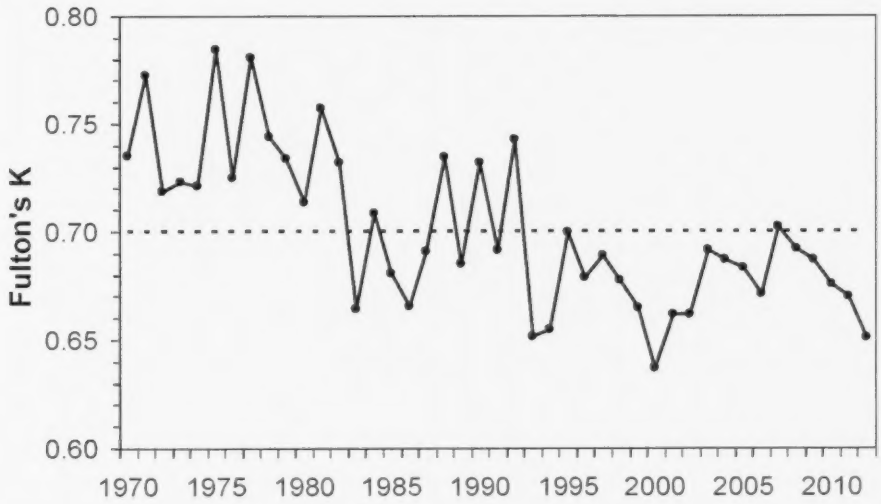


Figure 8. Annual mean condition (Fulton's K) for silver hake (length 21-44 cm) in the summer RV survey strata 440-483. Long term average (1970-2012) is indicated by dashed line.

Mean length at age for ages 2-6 declined from the early 1970s to the mid-1990s, then levelled off or increased for most ages, with the exception of ages 5 and 6 in recent years (Figure 9).

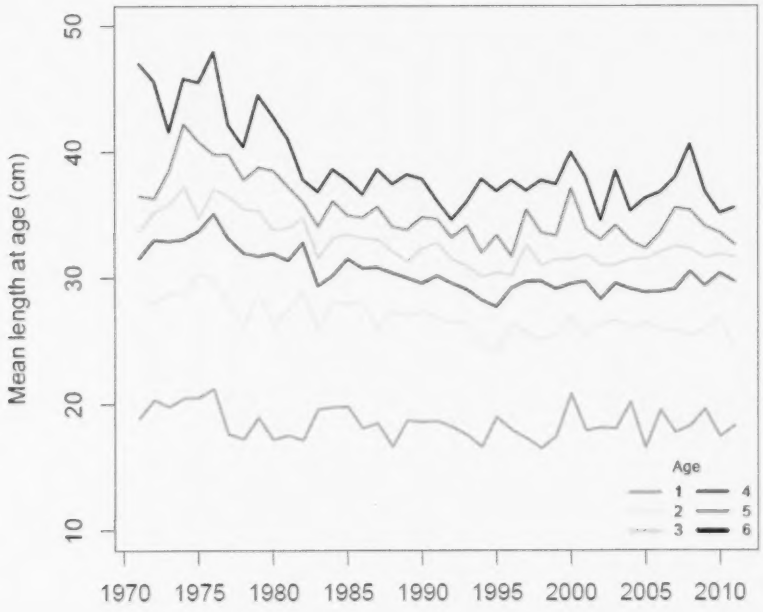


Figure 9. Mean length at age (cm) for Scotian Shelf silver hake from summer RV survey data.

Assessment Results

A logistic biomass dynamic model was fitted to commercial fishery catches and the summer RV survey biomass index from 1993-2012 to estimate trends in population biomass and fishing mortality rates, and provide biomass projections and harvest scenarios for 2013 (Cook 2013).

Model fits to the q-corrected summer RV survey biomass index captured the overall trends, as there was general coherence between the time series of survey data and model estimates (Figure 10). The 2011 (123,000 mt) and 2012 (120,000 mt) model estimates of population biomass were the highest for the 1993-2012 time series.

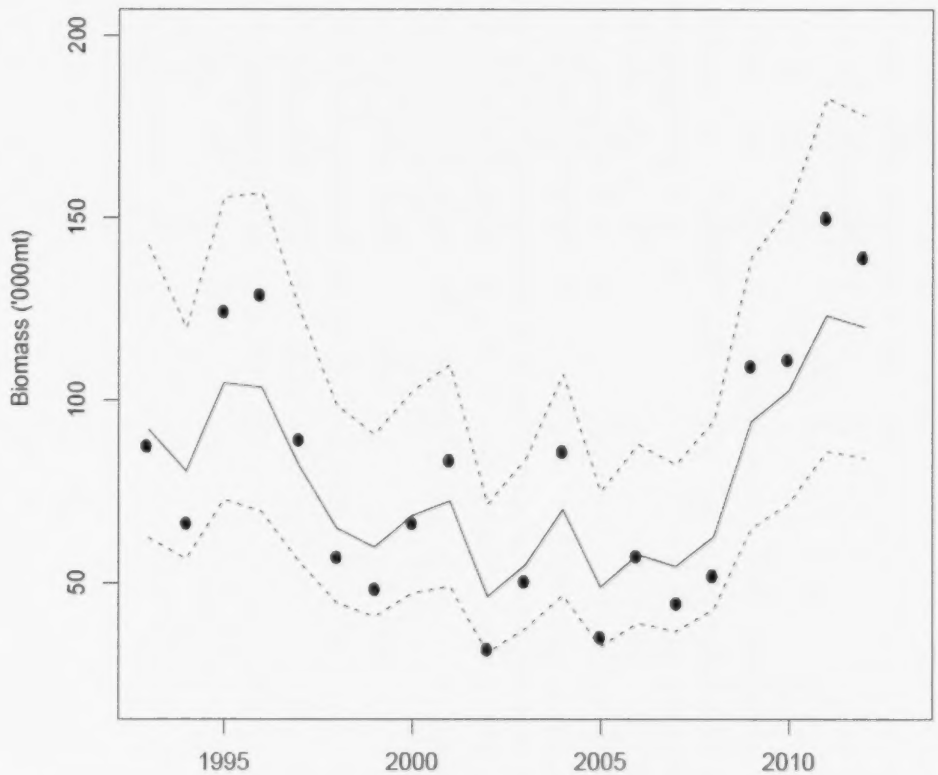


Figure 10. Model fits (solid line) to the q-corrected summer RV survey biomass index (points, $x10^3$ mt) from strata 440-483. Dashed lines represent 50% credible intervals for biomass estimates.

A retrospective analysis to examine the coherence of the model results through time indicates a tendency to overestimate the biomass by about 11% in years prior to 2008 (Figure 11).

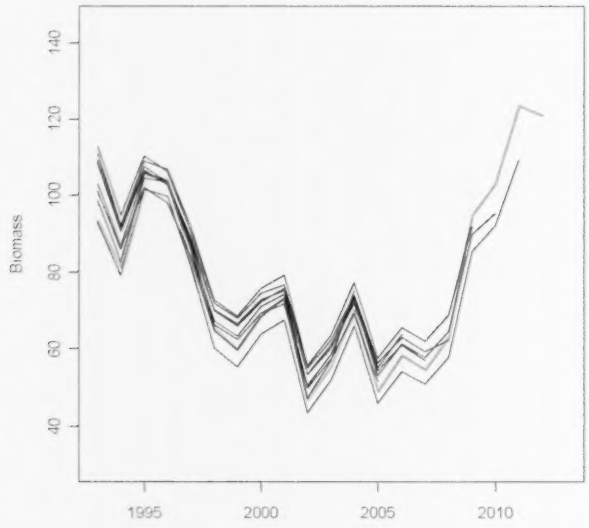


Figure 11. Retrospective plot showing the coherence of the estimated biomasses (x10^3 mt) from the model over the recent years. Red line: model run with full time series; black lines: consecutive model runs with the terminal year removed.

An analysis was conducted to assess the model's ability to project future biomasses. Biomass estimates in year *t* from the model were compared to projections in year *t* after removing one year biomass index and projecting forward one and two years using the observed landings (Figure 12).

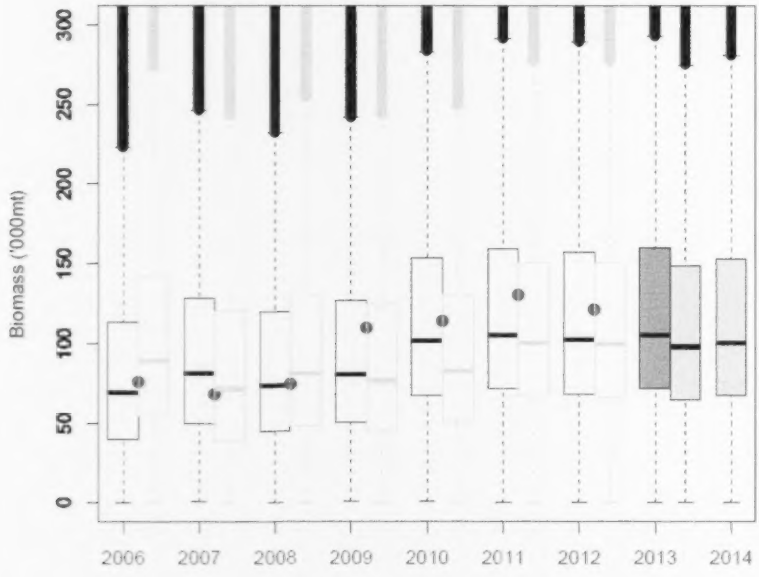


Figure 12. Projected (boxplots) one year (black) and two years ahead (grey) and model fitted estimates of biomass in '000 mt (points) for 4VWX silver hake from the logistic biomass dynamic model. The red boxplot represents the one year projected biomass for 2013 under landings scenario 2 (see Table 2). The pink boxplots represent the two year ahead projected biomasses under landings scenario 2.

Biomass reference points were calculated from the logistic biomass dynamic model outputs incorporating the process uncertainty estimated through a state space approach. The current median estimates of stochastic Maximum Sustainable Yield (MSY), Biomass at MSY (B_{MSY}), and Fishing Mortality at MSY (F_{MSY}) for 4VWX silver hake are 16,000 mt, 59,000 mt, and 0.32, respectively. Using the default values proposed in the DFO Precautionary Approach (PA) Policy (DFO 2009), 80% B_{MSY} is proposed as the Upper Stock Reference (USR=47,200 mt) and 40% B_{MSY} is proposed as the Limit Reference Point (LRP=23,600 mt) for 4VWX silver hake. F_{MSY} is proposed as the limit Removal Reference (RR=0.32). However, it should be recognized that these reference points were based on information from the recent time period (1993-2011). Also, they are for the entire stock area (indicated in red in Figure 1), though the majority of the fishery is prosecuted within Emerald and LaHave basins. The restrictions on geographic extent of the fishery may preclude exploitation as high as F_{MSY}, since this may represent a higher proportion of the stock biomass than is present in Emerald and LaHave basins and available to be caught.

Using these estimates for B_{MSY} and F_{MSY}, the relationship between stock size and fishing mortality can be tracked through time (Figure 13). For most of the years since 1993, estimated biomass has been above 80% B_{MSY}; although for several years during the early 2000s, stock sizes fell below 80% B_{MSY}. Annual fishing mortality (F) has remained below F_{MSY} throughout the time series of observed landings and estimated biomasses.

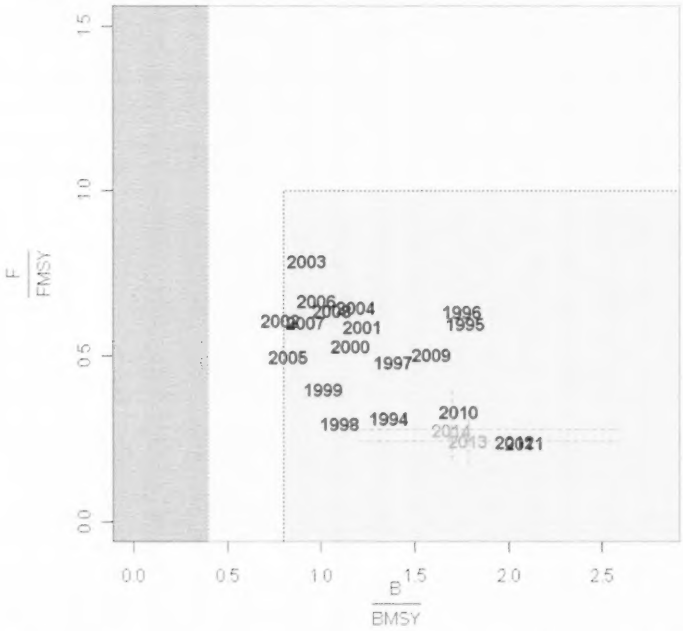


Figure 13. Phase plot of the ratio of current year fishing mortality (F) to F_{MSY} and biomass (B) to B_{MSY}. With one (2013) and two year (2014) projections under landings scenario 2 (see Table 2), landings at 9,900 mt. Colours represent stock status: red-critical; yellow-cautious, green-healthy.

Several landings scenarios were explored to assess their impact on the projected biomass estimate to July 2013 (Table 2) and to March 2014 (Table 3). For model fitting and catch projections, the July survey was treated as the pre-fishery biomass with annual landings accruing between July and June of the following year. The TAC is set prior to the fishing year, which begins in April and runs through to the following March. Scenarios to July 2013 assumed landings for the fishing year 2012-2013 were the same as the mean of 2009-2011 (9,900 mt). Given landings of 3,300 mt prior to the July 2012 biomass estimate, the landings used to project

to July 2013 were the sum of 6,600 mt and 28% of each scenario (Table 2: Landings used for projections). The 28% is the mean proportion of annual landings captured between April and June across the last six years. Projecting to March 2014 used the remainder of the catch scenario (71.2%; Table 3).

Biomass is expected to be lower in 2013 than in 2012 regardless of the landings scenario. The probability distributions of projected biomass estimates from each scenario were compared against 80% and 40% of B_{MSY} to determine the probability of projected July 2013 biomasses falling below these reference levels. Across all landings scenarios examined in the projections, the probability of biomass falling below 80% B_{MSY} in July 2013 was less than 0.1. With landings at F_{MSY} (45,100 mt) the probability of falling below 80% B_{MSY} increases to 0.13 (Table 2).

Biomasses for 2014 are expected to decrease from the 2013 levels, although to a lesser degree. The probability of projected March 2014 biomass falling below these reference levels was less than 0.15. With landings at F_{MSY}, the probability of falling below 80%B_{MSY} increased to 0.32 (Table 3).

Projections from an aggregate population model, such as that used here, assume mean recruitment and growth across the projected years. The ability of the model to describe future biomass more than one year ahead is uncertain given that silver hake have highly variable recruitment patterns and the fishery prosecutes recruiting individuals (ages 1-2).

Table 2. Results of different landings scenarios on the projected biomass (x10^3 mt) estimates for July 2013. Accompanying the median and credible intervals for 2013 biomass are the probabilities of biomass falling below 80% and 40% percentages of B_{MSY}.

	Scenario ('000 mt)	Landings used for projections (July-June) ('000 mt)	Fishing Mortality	Median Biomass 2013 ('000 mt)	50%CI Biomass 2013 ('000 mt)	Probability of 2013 Biomass falling below X% of B_{MSY} Levels 80%	40%
TAC	0	6.6	0.05	108	74-164	0.062	0.006
	9.89[1]	9.5	0.08	105	71-160	0.074	0.007
	12	10.1	0.08	105	71-159	0.077	0.007
	15	11	0.09	104	70-158	0.081	0.007
	18	11.9	0.09	103	69-157	0.085	0.008
F_{MSY}	45.2	19.7	0.15	95	62-148	0.127	0.014

1Landings scenario 2: 9.89 is the mean for the last 3 years.

Table 3. Results of different landings scenarios on the projected biomass (x10^3 mt) estimates for March 2014. Accompanying the median and credible intervals for 2013 biomass are the probabilities of biomass falling below 80% and 40% of B_{MSY}.

	Scenario ('000t)	Landings used for projections (July-March) ('000 mt)	Fishing Mortality	Median Biomass 2013 ('000 mt)	50%CI Biomass 2013 ('000 mt)	Probability of 2013 Biomass falling below X% of B_{MSY} Levels 80%	40%
TAC	0	0	0	108	75-162	0.085	0.023
	9.89[1]	7.1	0.07	100	67-153	0.114	0.025
	12	8.6	0.08	98	66-151	0.12	0.025
	15	10.7	0.10	96	64-148	0.137	0.029
	18	12.8	0.12	93	61-145	0.144	0.030
F_{MSY}	45.1	32.2	0.29	70	40-119	0.327	0.125

[1]9.89 is the mean for the last 3 years.

Ecosystem Considerations

Bycatch in the silver hake fishery is limited by the use of a mandatory separator grate in the codend and by the restriction of fishing activity to deeper water in the inshore basins or off the edge of the shelf. Observer coverage of this fishery has averaged 6% by weight in recent years (2002-2011). Based on observer records, bycatch constitutes less than 4% of the total observed catch. The most common bycatch species are herring (1%), red hake (0.4%), unspecified redfish (0.4%) and spiny dogfish (0.4%). Other species of possible concern are rare bycatches, such as a single recorded capture of a basking shark.

The fishery occurs primarily on soft-bottom habitat in Emerald and LaHave basins. A part of a globally unique population of the large-structure forming sponge, *Vazella pourtalesi*, is also found in this area and is known to be vulnerable to bottom-tending fishing gear.

Sources of Uncertainty

In this assessment, only the RV survey strata 440-483 were used, excluding data from the Bay of Fundy. The stock boundary between the Scotian Shelf and Bay of Fundy, if one exists, is imprecise and may vary from year to year.

Dynamics of an aggregate population model may not closely track the dynamics of the population. The model assumes mean recruitment and does not account for the variability in year class strength. This impacts both the annual estimates of biomass and the catch projections. Catch projections beyond the current year are based on very little information and are highly uncertain, particularly given that the fishery is very reliant on age 1 fish.

CONCLUSIONS AND ADVICE

Landings of 4VWX silver hake in the fishing years ending in 2010 and 2011 were 8,396 mt and 9,231 mt, respectively, relative to a quota of 15,000 mt. Landings are constrained by market conditions; there is no indication that a catch lower than the quota is related to a reduced abundance. Landings have been maintained at a low level since 2000, with most catches occurring in the basins since 2005. The current silver hake fishery catches primarily fish aged 1-2.

Total survey biomass on the Scotian Shelf has been increasing since 2008 and is now comparable to levels in the late 1980s. Age 2+ (a proxy for spawning stock biomass) and 2+ female biomass have also increased. The 2009 year class is the largest in the time series. The strong 2009 year class made a significant contribution to the fishery in 2011 and is expected to be important in 2012 catches. The incoming 2010 and 2011 year classes are both above average. Condition has been generally below the long term average since the early 1990s and is currently near the lowest level in the time series.

The 2011 (123,000 mt) and 2102 (120,000 mt) model estimates of population biomass were the highest for the 1993-2012 time series. The current median estimates of stochastic Maximum Sustainable Yield (MSY), Biomass at MSY (B_{MSY}), and Fishing Mortality at MSY (F_{MSY}) for 4VWX silver hake are 16,000 mt, 59,000 mt, and 0.32, respectively. Based on these, 80% B_{MSY} is proposed as the Upper Stock Reference (USR=47,200 mt) and 40% B_{MSY} is proposed as the Limit Reference Point (LRP=23,600 mt) for 4VWX silver hake. F_{MSY} is proposed as the limit Removal Reference (RR=0.32).

Biomass is expected to be lower in June 2013 and March 2014 than in 2012 regardless of the landings in the 2012/2013 fishing year. Across all landings scenarios examined in the projections (TAC=0-18,000 mt), the probability of biomass falling below 80% B_{MSY} in July 2013 was less than 0.1. With landings at F_{MSY} (45,100 mt) the probability of falling below 80% B_{MSY} increases to 0.13. The probability of projected March 2014 biomasses falling below these

reference levels was less than 0.15. With landings at F_{MSY}, the probability of falling below $80\%B_{MSY}$ increased to 0.32.

Projections from an aggregate population model, such as that used here, assume mean recruitment and growth across the projected years. The ability of the model to describe future biomass more than one year ahead is uncertain given that silver hake have highly variable recruitment patterns and the fishery prosecutes recruiting individuals (ages 1-2).

Based on observer records, bycatch constitutes less than 4% of the total observed catch. The fishery occurs primarily on soft-bottom habitat in Emerald and LaHave basins. A part of a globally unique population of the large-structure forming sponge, *Vazella pourtalesi*, is also found in this area and is known to be vulnerable to bottom-tending fishing gear.

SOURCES OF INFORMATION

This Science Advisory report is from the December 11, 2012, Review of the Framework and Assessment for 4VWX Silver Hake: Part 3 - Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Cook, A.M. 2013. Bayesian state space surplus production model for 4VWX silver hake. DFO Can. Sci. Advis. Sec. Res. Doc. 2013\009.

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